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REVIEW OF THE LATEST TECHNOLOGY IN CARTOGRAPHIC DATA ACQUISITION, MANIPULATION, STORAGE AND PRESENTATION, WITH SPECIAL EMPHASIS ON POTENTIAL APPLICATIONS IN DEVELOPING COUNTRIES: AUTOMATED MAPPING PROJECTS: DEVELOPMENT AND APPLICATION OF DIGITAL CARTOGRAPHIC DATABASES, INCLUDING DIGITAL TERRAIN MODELLING

The Vector Product Format: an overview

Paper submitted by the United States of America**

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INTRODUCTION

The National Imagery and Mapping Agency is chartered with providing products for the U.S. Military, Defense Agencies, and maritime customers. Increasingly these products are being produced in digital form. NIMA provides digital geospatial products primarily in three formats: Vector Product Format (VPF), Raster Product Format (RPF), and Text Product Format (TPF). Vector products account for the largest growth in the demand for digital data. NIMA produces a wide range of products which incorporate the VPF structure. The use of VPF for the distribution and direct application of geospatial information continues to expand.

BACKGROUND

Unlike many other government agencies which collect geographic information for internal use within their own organization, NIMA collects and furnishes geographic information, cartographic data, geodetic information, and navigation information to fulfill customer requirements. U.S. Federal, state, and local agencies collect and use geospatial information for use in forest, land, water, and energy resource management, as well as for public works, urban planning, and understanding population trends. Typically this information is provided to the public and the private sector as a low-cost by-product to promote growth, development, and recreation. The U.S. Department of Defense chartered NIMA with the responsibility to provide mapping, charting, geodetic, and geospatial information for use by the Army, Navy, Marines, Air Force, and Intelligence agencies, as well as for maritime navigation world wide. These products are used in a wide variety of activities such as strategic, regional, and tactical planning, mission planning and rehearsal, modeling for system development and performance testing, cockpit moving map display, on-board navigation, and many other applications.

As a customer oriented organization, NIMA maintains an active requirements collection component dedicated to working with customers to understand the type and format of data they require, as well as determining the geographic areas of the world for which they will need information. This component, as well as research and development groups within NIMA, works with weapons and other systems developers to insure that as new military systems and practices are developed, NIMA will provide the data they require. Data formats and digital products are developed using an iterative prototype design process to insure that NIMA products meet customer needs, and provide data in a readily usable form.

Geographic information standards such as the Spatial Data Transfer Standard (SDTS, U.S. Federal Information Processing Standards - FIPS 173) and NIMA's internal Mapping Charting Feature Data Exchange Standard (MC&GFDES) are examples of very robust standards designed purely for information exchange. MC&GFDES was developed for the exchange of data within a very large integrated production system. SDTS was developed to support the exchange of spatial data of any type between organizations using, in many cases, proprietary Geographic Information Systems. Data type/content can vary so broadly that it is impossible to write a general purpose translator designed to handle all SDTS possibilities. As a robust exchange standard SDTS is not designed to reduce the size of the data for Ease of distribution, nor provide indices for rapid access, nor carry redundant or pre-computed data for ease of access and use. It was not intended to be used for the distribution of products. FIPS 173 Paragraph 8 (Applicability) states: FIPS SDTS is not intended to facilitate product distribution of spatial data in a form designed for direct access by application software specific to a particular data structure, class of computer platform, or distribution media. Product standards such as RPF and VPF must support the use of application software that can access information regardless of variation in content. A product standard must efficiently store information to minimize the number of tapes or discs needed to distribute the data. It must incorporate indices providing users efficient access to information.

THE VPF STANDARD

The VPF standard defines the conceptual and physical data model on which all NIMA vector products are based. It uses a geo-relational model which is physically organized into five hierarchical levels: Database Level, Library Level, Coverage Level, Feature Level, and Primitive Level. The geospatial feature is the central concept of the VPF data model. Real world features are modeled by describing their location (where) and their properties (what). The Primitive Level carries the location information using four basic primitives: nodes, edges, faces, and text. These are implemented in five types of primitive tables: Node Tables, Edge Tables, Face Tables, Ring Tables (which link faces to edges), and Text Tables. These tables contain topologic relationships and coordinate data. Feature tables are used to describe the properties of a geospatial feature. Each record in a feature table identifies the feature, its attributes, and its primitive(s). Four types of feature/primitive relationships are possible: one-to-one, many-to-one, one-to-many, and many-to-many. Sets of features and primitives form coverages, which are grouped in libraries; a collection of libraries form a database.

VPF coverages group features by topologic relationships ranging from no explicit topology to full topologic relationships for all primitives. Varying degrees of integration are supported. When a product does not require relationships among data types, data can be stored in separate coverages; when full topology is required features may be combined into a single coverage. Complex features, groups of features collected together and handled as a single entity, may be modeled. Utilizing these concepts products may be designed as simple or as complex as necessary facilitating efficient storage and use.

Limitations caused by restrictions in computer memory or distribution media capacity require that

large geospatial databases be divided into manageable units, or tiles. VPF supports tiling using a concept of organizing primitives by geographic units and provides inter-tile topology to maintain geographic features in a logically continuous manner across tile boundaries. To the user, the data appears as one seamless unit.

Some other features of the VPF which enhance the utility of geographic information are:

Self Describing Format - each VPF level has header tables that describe the information contained at that level and a description of the level below. Each VPF table has a header describing the table. This allows software developers to design utility software which can adapt to any VPF database regardless of product design.

On-line Data Dictionary - The VPF data dictionary allows the definition of features and attributes to be carried with the product to avoid misinterpretation by users. The VPF utilizes "Value Description Tables" that specify and describe the feature attributes used in each coverage. Users can employ this capability when adding their own data to the database. They can describe feature and attributes which have been developed solely for their own purposes. These can be defined in the database and passed on for all to use. This allows each coverage to be used by a wide range of users without prior knowledge of a coding system - enhancing interoperability and insuring the data is interpreted correctly.

Data Quality - VPF provides the capability to carry data quality information at the Library, Coverage, and Feature Level. This information will help the user perform geographic analysis. It allows users to weigh a product's accuracy, currency, and completeness when performing analysis.

The VPF standard defines a general database structure and rules for how to model geospatial feature geometry, topology, and attribute information. It does not define what features, geometry, topology, and attributes are to be carried in a data set. Product Specifications are used to describe what is to be included in a data set using the rules defined by the VPF standard. They specify what type of geometry: x-y coordinates on a plane or latitude-longitude coordinates on an ellipsoid, whether these coordinates will be 2-dimensional or 3-dimensional; what level of topology; and what features and what attribution will be carried in a product. All within the limits defined by the VPF standard.

As a Military Standard, VPF documentation is available to the public through the Defense Printing Service Detachment Office. Previously known as MIL-STD 600006, the VPF military standard has been updated and the new version has been assigned MIL-STD 2407. The standard can be accessed

through the NIMA Homepage on the INTERNET (http://www.nima.mil). The standard can also be ordered by writing to:

Defense Printing Service Detachment Office:
Standardization Document Order Desk
Building 4D
700 Robbins Ave.
Philadelphia, PA 19111-5094
USA

To understand each NIMA product, a product specification must be used along with the VPF standard. These military specifications describe an implementation of the VPF standard.

VPF DATA AVAILABILITY

A wide variety of geospatial information is available in VPF. Development of new products continue as NIMA customer's requirements and applications expand. Many of these product specifications are available through the NIMA homepage on the INTERNET (http://www.nima.mil).

Digital Chart of the World/VMap Level 0

The Digital Chart of the World (DCW) is a comprehensive 1:1,000,000 scale equivalent resolution basemap of the world. The database is contained on four compact disc read only memory (CD-ROM). The database contains more than 1,500 megabytes of vector data and is organized in 10 thematic layers. The data includes major road and rail networks, major hydrologic drainage systems, major utility networks (cross-country pipelines and communication lines), all major airports, elevation contours (1000 foot(ft), with 500 ft and 250 ft supplemental contours), coastlines, international boundaries and populated places. The DCW also includes an index of geographic names to aid in locating areas of interest. The DCW is designed to support geographic information system (GIS) applications.

Edition 2 of the DCW will be released March 1997 as VMAP0 and is undergoing several design changes incorporating it into the Vector Map (VMap) series of products. International boundary information will be updated incorporating the latest changes as approved by the U.S. State Department. Vegetation information will be expanded to include all of North America. Global bathymetric information will be added in the form of depth contours. VMAP0, as with all NIMA vector products, uses the Feature Attribute Coding Catalog (FACC) which is Part 4 of the Digital Geographic Information Exchange Standard for feature and attribute definition. The DCW is available to the general public (as will VMAP0) through the U.S. Geological Survey, Earth Science Information Center (303-236-7477). The VMap0 is described in military specification MIL-D-89039.

World Vector Shoreline+

World Vector Shoreline (WVS+) is a product contained on a single CD-ROM which contains the world's shoreline at an equivalent resolution of 1:250,000. It also includes international boundaries including off-shore territorial boundaries and country names. Also included are representations of the world's shoreline at equivalent resolutions of 1:500,000, 1:1,000,000, 1:3,000,000, and 1:12,000,000. WVS will be available to the general public. Any vendor or publicly available software capable of reading VPF will be able to provide access to this database. The WVS+ is currently in production and will be available for public sale in December 1996.

Digital Nautical Chart

Digital Nautical Chart (DNC) products consist of VPF databases comprised of varying resolution libraries over a specified operational area. These libraries contain maritime significant geographic and navigation information typically found on standard nautical charts. Each library consists of 12 coverages: Cultural Landmarks, Earth Cover, Environment, Hydrography, Inland Waterways, Land Cover, Limits, Aids to Navigation, Obstructions, Port Facilities, Relief, and Data Quality. As an example a DNC may contain a General Library containing 1:1.2 million scale equivalent data; a Coastal Library containing 1:300,000 scale data; an Approach Library containing approximately 1:75,000 scale data; and a Harbor Library containing 1:20,000 scale equivalent information. When used by a navigator on-board ship, varying levels of detail are accessed by switching libraries as needed. Several DNCs have been completed and production is underway to cover the world's major ports by 1997. This will be produced by digitizing 4000 nautical charts. The DNC may become available to the general public pending a legal review by the International Hydrographic Organization. Its design is described in military specification MIL-D-89023.

Vector Map

Vector Map (VMap) is a suite of products which contain basic topographic geospatial data at a variety of levels of resolution. All VMap products contain identical thematic coverages: Boundary, Data Quality, Elevation, Hydrography, Industry, Physiography, Populated Places, Transportation, Utilities, and Vegetation.

VMap Level 0--VMap Level 0 is identical to the DCW described above.

VMap Level 1--VMap Level 1 will consist of approximately 234 CD-ROMs covering the world with 1:250,000 scale equivalent information. World coverage is expected by 2000. VMap is fully described elsewhere in this publication. VMap Level 1 CD-ROMs covering areas which are not bound by international agreements restricting release will be made available to the general public. VMap Level 1 design is described in MIL-V-89033.

VMap Level 2--VMap Level 2 consists of information with a resolution equal to 1:50,000 to 1:100,000 scale data. Individual Level 2 products cover small geographic areas determined by the

geographic operational requirements of NIMA's customers. Because of the sensitivity of this large scale information within many countries of the world, most Level 2 data will be restricted. The VMap Level 2 design is described in MIL-V-89032.

Urban VMap--As the name implies UVMap products cover urban areas. These products provide information at resolutions ranging from 1:5,000 to 1:50,000. Although it uses the same 10 thematic coverages as other VMap products, feature content and the level of attribution are much richer. Like Level 2 many UVMap products will not be releasable to the general public. The UVMap product design is described in MIL-U-89036.

VPF APPLICATIONS

Listed below are several software applications packages which make use of VPF products. The products mentioned are just a sampling to provide an understanding of what is available. It is not a recommendation; any product which uses VPF and is not mentioned, was left out unintentionally.

VPFView Software

VPFView software is designed to access any database implemented in VPF. It allows the display of chosen combinations of features or themes for a user selected geographic area of interest. The software supports the display of VPF databases directly from CD-ROM, hard drive, or diskette without loading or converting the data. Display scale can be changed by zooming in or out. Portions of a database can be copied from removable storage media and saved on a computer's hard disk in VPF. Simple plots can be generated in postscript format. Source code is available to provide developers methods for importing the data into their proprietary systems. A users manual is included. Both VPFView DOS (Order Number PB94-501715GEI) and VPFView UNIX (Order Number PB94-501723) versions are available through the U.S. National Technical Information Service (NTIS):

U.S. Department of Commerce
NTIS
5286 Port Royal Road
Springfield, VA 22161
703-487-4650, FAX 703-321-8547

MC&G Utility Software Environment

MC&G Utility Software Environment (MUSE) Version 1.0 was developed by the NIMA to provide a sample suite of software exploiting NIMA digital products. MUSE operates in the Windows,Macintosh, and SUN MOTIF/Openlook environments. Full source code is provided to allow users to understand and develop their own versions of access software. MUSE provides routines to access and process a wide variety of NIMA products such as: Arc Digitized Raster Graphics (ADRG), Compressed ADRG (CADRG), Controlled Image Base (CIB), Digital Terrain Elevation Data (DTED) and a wide variety of VPF products. MUSE supports raster importing,

vector importing, demonstration/briefing display tools, map fusion (overlaying raster data with vector information), standard NIMA datum transformations and coordinate conversions, line of sight computation and display, and perspective scene generation by fusing raster map data and elevation data. MUSE will extract data from VPF products; spatial extent is defined by entering geographic coordinates for the desired area; thematic selection is performed by allowing the users to define the coverages, libraries, and feature types to be accessed. VPF databases can be filtered by attribute by creating thematic expressions. MUSE is distributed by NIMA on CD-ROM along with full documentation and sample data sets.

MIGRATION TO DIGEST

As a U.S. Military Standard VPF is a controlled document, a stable design model, used for procurement and referenced by product specifications. The VPF geographic data model is based on the geographic model defined in the Digital Geographic Information Exchange Standard (DIGEST). VPF is equivalent to the implementation model defined in DIGEST Annex C, Vector Relational Format (VRF). DIGEST was developed by the Digital Geographic Information Working Group (DGIWG) a group of military map producers from 11 NATO nations. DIGEST, NATO Allied Geographic Publication 3 (AGeoP 3), has been ratified as NATO Standardization Agreement 7074 (STANAG 7074). In keeping with the DoD trend of moving away from the use of military standards, future producers and users implementing this vector relational model will drop the reference to the VPF Military Standard, and instead reference the internationally controlled DIGEST, STANAG 7074.

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